7. ANTICIPATED CONTRIBUTIONS TO MOTOR VEHICLE EMISSIONS ASSESSMENTS AND RECOMMENDED RESEARCH

This chapter will review the contribution to the fields of transportation and air quality planning presented in this report, and present a future research agenda. Individuals and groups have developed spatially-resolved emission estimates previously, but none have done so in a single, comprehensive unit. Groups have used geographic information systems (GIS) as a pre-processor, preparing data for outside modeling, and they have been used as a post-processor to help visualize results. The approach described in this report relies on the capabilities of GIS to manage the process from start to finish.

Research into transportation and air quality has made significant progress in the last several years, but results have not been formally incorporated into comprehensive and flexible modeling regimes. The proposed model framework successfully incorporates existing emission research into a single model. Further, the model is flexible to the addition of new research, an important design element needed due to the dynamic condition of transportation and air quality research. Finally, this report provides important insight into the current conditions of emission-specific spatial data, and provides a tool that can be used to define the limits of disaggregate modeling approaches. This exploration into the spatial modeling of exhaust emissions provides substantial progress towards the development of computer tools that can aid metropolitan transportation planners in their attempt to identify the impacts of transportation change on air quality.

7.1. Impacts

The potential impacts of this research are significant. It has been widely recognized that there are theoretical problems with the current modeling regime, especially with the speed correction factor emission rate models. If a spatially resolved modal emission model becomes accepted for use for conformity and inventory modeling, the types of mitigation strategies available to local and state governments change dramatically. Under the current modeling system, transportation planners and engineers have only two ways to reduce emissions: reduce vehicle miles of travel and/or optimize average speeds to points deemed significant by the models. Both options probably reduce mobility and accessibility enjoyed by the transportation systems. If modal models are developed, much more diverse and creative strategies become available. Any strategy that reduces the number of high-emitting vehicles or reduces the occurrence of hard accelerations and decelerations will reduce mobile emissions. Reducing volume may be less important than improving traffic flow through ITS strategies, signal timing, or even lane additions. The new modal approaches may show that mobility and accessibility can increase as mobile emissions decrease.

Further, spatially-resolved estimates allow planners to prioritize certain locations for mitigation strategies because of their disproportional contribution to ozone formation due to topographic or climatic features. The spatially-resolved estimates at proper resolutions allow local transportation planners and traffic engineers to develop small-scale changes that reduce the net mobile emissions produced in their jurisdictions.

One other impact is that new car standards may be altered to reduce the occurrence of fuel enrichment resulting from high power demand. This may divert mobile emission reduction strategies away from operational conditions and more towards those strategies that impact engine starts.

7.2. Major Contributions

This section provides a discussion of how the objectives described in Chapter 1 were accomplished. The objectives were:

- *Develop an automobile exhaust emissions model that maximizes comprehensiveness, flexibility and user friendliness.*
- *Provide a research tool that allows for the testing of variable levels of motor vehicle emission model spatial aggregation.*
- *Demonstrate the benefits of using GIS for emissions modeling.*
- *Identify research and data needs for improved spatial and temporal emissions modeling.*

7.2.1. Model Design and Development

Chapter 3 lists specific model design parameters that were identified through background research. This section describes how the model is successful or unsuccessful in accomplishing those design goals.

The following model design parameters were successfully included:

- *All estimates (emissions, vehicle activity, etc.) must be capable of being validated.*
- *The model must be designed to easily incorporate new findings.*
- *The model must use available, or nearly available, data.*

- *The model must use as large a spatial scale as data will allow.*
- *Develop estimates of the production of automobile exhaust pollutants CO, HC, and NO_x in space and time.*
- *Separate and quantify high-emitting vehicle emissions.*
- *Include SCF emission rates.*
- *Include emission rates from the statistical approach.*
- *Include activity measures from the travel demand forecasting models.*
- *Prepare for inputs from future simulation models.*
- *Utilize geographic information systems.*
- *Appropriate documentation.*
- *Appropriate terminology.*
- *Modular system design.*
- *Open input and output data formats.*
- *Intuitive model process.*
- *Easy to understand and use.*
- *Model should reside in a GIS.*

The following model objectives were only partially accomplished:

- *The model must produce automobile exhaust emission estimates that are capable of being statistically verified.*

The resulting model is developed around data and procedures that have stochastic distributions. This factor makes the model statistically verifiable. However, actual verification of the current model results must wait until individual components are validated.

- *Anthropogenic NO_x estimate accuracy important in predicting ground-level ozone.*

NO_x is not treated in a manner distinguishing it from the other pollutants. However, the inclusion of modal parameters allows better predictions of NO_x, which varies with speed and acceleration.

- *Comprehensive representation of vehicle technologies.*

As mentioned in chapter 6, substantial differences exist between fleet averages and the ability of the MEASURE model to comprehensively represent the operating fleet in space and time. The major problems stem from the need to have a good routine for identifying vehicle characteristics given the vehicle identification number. When this is done, comprehensive representation will be accomplished. On-road vehicles distributions need more research.

- *Separate start, hot-stabilized, and enrichment emission quantities and locations.*

Start emissions are separate. Hot-stabilized and enrichment emissions are combined into the running exhaust estimates. This approach includes enrichment, unlike other models, but not separately. Breaking the two modes (enrichment and running exhaust) into separate procedures requires more information unavailable for this stage of the research. However, the model framework can easily incorporate separate procedures.

7.2.2. Tool for the Exploration of Spatial Aggregation

The purpose of developing a tool that has flexible aggregation capabilities is that gridded emissions are required to predict ambient of levels of ozone and other pollutant concentrations. Future photochemical models will require a minimum one kilometer grid cell aggregate estimate of mobile source pollutant production by hour. As research into ambient air quality is conducted, the spatial scale of ozone formation and pollutant dispersion will continually be redefined, placing spatial parameters on input data. Further, emission rate models used for inventory purposes will have to have a level of spatial aggregation based on data availability and algorithm accuracy. To aid the local transportation planners in their efforts to reduce automobile pollution, models must develop accurate estimates for transportation facilities. The facility-estimates are aggregations of individual vehicles over time. Therefore, it is important that the amount of aggregation or disaggregation that can be accomplished with existing data and knowledge is identified. These issues are crucial in defining the scope of research being conducted around the country in emission modeling.

The current model has the capability to explore levels of spatial aggregation. It can use data from any size zonal aggregation, and it can re-allocate estimates to any size grid cell. Once validated, it can be used to help research the issues mentioned in the previous paragraph. The actual impacts of various levels of spatial aggregation on the accuracy of the emission estimates will vary with the spatial quality of the input data. As the spatial structure varies, so will the accuracy.

7.2.3. Value of Geographic Information Systems

Geographic information systems provide numerous advantages to the spatial modeling of exhaust emissions.

- *Spatial data organization*

Data in the model were organized based on their spatial character. Structuring the multiple layers of data in this manner provides data connectivity that would be difficult without GIS and topology.

- *Spatial data joining*

During the modeling process, datasets of different characteristics are merged together to form a single entity. Specifically, GIS allowed the travel demand forecasting model network to have improved spatial resolution by conflating to a spatially accurate road database. This capability of GIS also allowed linkages to occur between the various area sources of information (TAZs, land use, Census, etc.).

- *Spatial query*

GIS provided the ability to search data by locational parameters. Specifically, the technique used to predict the on-road fleet distribution required for the identification of the fleet registered within a certain distance from the individual road segments.

- *Spatial aggregation*

GIS provided the ability to aggregate irregular polygon data and line data into regular user-defined grid cells. This capability makes GIS vital for efficiently developing mobile emission inventories, regardless of the modeling approach used.

- *Spatial data visualization*

The map-making and graphic display capabilities found in most GISs are extremely useful in communicating model results to individuals from various technical backgrounds. Given the importance of mobile emissions in determining transportation improvements, this feature has significant value.

7.3. Future Research

Future research is recommended in three major areas; model validation, model improvement, and model additions. Without model validation, the ultimate value of the model described in this report is lost. During model development and testing, it became evident that certain strategies could be improved with designed experiments. The following sections describe some specific actions that can be taken to expand the model for use by transportation and air quality planners.

7.3.1. Model Validation Strategies

The model validation strategies follow the modular nature of the software. Testing each module's results through designed experiments would answer the accuracy questions that would allow the model to proceed beyond the prototype stage. Prior to model validation, the input datasets should undergo significant quality assurance testing to identify errors and temporal conflicts with other datasets.

7.3.1.1. Spatial Environment

The spatial environment module accuracy relies on the spatial accuracy of the input data, varying with new implementation sites. Procedures used in the model to manipulate this information do not require validation. Each new modeled area should undergo a data verification and validation stage. At minimum, this should include identifying the last date the information was updated and the estimated absolute spatial accuracy of the data.

7.3.1.2. Fleet Characteristics

The process used to develop fleet characteristics needs substantial validation efforts. The intention of the modules is to develop an accurate profile of the operating fleet. The problems identified with the VIN decoder and 'lookup' routines can be solved through database and software development and are not mentioned in the validation phase. However, their effects on the accuracy of the estimate are included in the list of recommended validation efforts.

- *Zonal fleet distribution study:* A study is needed that can identify the distribution of vehicles that are registered within a zone. This could be accomplished through the ingress, egress study of a number of neighborhoods. The difficulty will be defining an appropriate sample size and definition (income, family size, etc.).
- *On-road fleet distribution study:* A study is needed that can identify the technology distributions of the on-road fleet. Currently, data capable of doing this have been collected (using video cameras) for over fifty sites. The difficulty is developing sample sets for different road classes at different times of the day. The current equipment can only be used across one lane of traffic, limiting the scope.

7.3.1.3. Vehicle Activity

Since vehicle activity estimates rely heavily on the travel demand modeling process, efforts to validate the travel model significantly improve the ability of this model to calculate errors. However, validating the engine start estimates can be accomplished through the same ingress / egress study mentioned previously.

- *Engine start activity study:* A study is needed that can identify the number of engine starts that occur by time of day within a zone. This could be accomplished through the ingress, egress study of some neighborhoods. However, this study would not need the video camera, but could rely on loop detectors. This would also allow data to be collected over a long period of time.
- *Road segment activity study:* A study is needed that can measure the volume and average speed of road segments modeled in the travel demand model by hour of the day. The Atlanta Advanced Traffic Management System (ATMS) could be used to validate interstate estimates. Other road classifications could be studied using other techniques. Again, an appropriate sample size will have to be determined.
- *Speed and acceleration profile study:* Studies that measure the speed and acceleration profiles accuracy are needed. This is currently being accomplished by researchers at Georgia Tech for interstates and ramps.

7.3.1.4. Facility and Gridded Emissions

Facility emission estimates must be validated. Currently, remote sensing technology allows for road segment, hourly pollutant production estimates to be accomplished. The devices do not measure NOx, but it can be estimated using other pollutant concentrations. Measurements on multi-lane roads are difficult to do. An alternative for major roads is an upwind-downwind study where sensors are placed at regular intervals along both sides of a road. This type of study is expensive and unreliable in areas with large amounts of background pollution.

Outside of the remote sensing data collection, little can be done to directly measure emission production from operating vehicles. Many researchers are working on the issue, and technologies may develop that would make this possible.

7.3.2. Model Algorithm Improvement

There are some specific issues in the model design that could be studied to improve the accuracy of the estimates. While model validation is important in measuring current capabilities, these issues could improve the ability of the modules to accurately predict their phenomena.

- *Home location vs. registered address:* The registered dataset includes address fields that are supposed to represent the homes sites of the vehicles. Because registration tax rates differ among jurisdictions, and because people move, there is need to identify the proportion of the database that has incorrect data.
- *Fraction of total vehicle operation by vehicle type:* The registration dataset represents all vehicles that are licensed to operate on the road. The actual operating fleet may look quite different. It was evident in the two sites discussed in section 6.2.2 that the operating fleet may be much newer than the registered fleet.
- *On-road vehicle distribution search pattern:* In section 6.2.2, there was some evidence that indicated that the radial search pattern used in the model may be inappropriate for determining a local operating fleet. Research into the size and shape of the search pattern could significantly improve the capability of predicting the on-road fleet distribution.

7.3.3. Model Additions Research

The current model scope is limited to automobile exhaust emissions. Moving to a complete mobile emissions model involves adding much more information and data. Some of the major items are listed below:

- *On and off network grade distributions and impacts:* Comprehensively, the impacts of grade on engine load have not been identified in the research. Since road grade has spatial variability and could have significant impact on the load on an engine, it should be included in the research design. This may mean moving to a more detailed emission rate model that has emission rates for engine load conditions.

- *More speed / acceleration matrices:* The model needs more speed and acceleration data to have a comprehensive view of modal activity on all road types. Currently, the model is limited to eleven different profiles.
- *Intersection activity:* Intersections are the one facility-type missing from the current model. Intersections will be significant to producing accurate emissions due to the extreme variability of modal activity.
- *Other motor vehicles types:* Currently, only automobiles are modeled because there are only a few vehicle emission tests for non-autos. A comprehensive mobile source model must include all vehicles types.
- *Load-based approach:* A load-base approach to predicting emissions will allow enrichment emissions to be separately identified, an original model design objective.
- *Non-exhaust mobile emissions:* Exhaust emissions only make up a portion of the overall mobile emission modes. Evaporative emissions need to be included in future models.
- *External / internal trips:* Currently, external / internal trips are excluded from the models predictions of start activity. The return trips of these vehicles are ignored, and they could represent a significant portion.

Overall, the model was successfully designed and developed according to research backed parameters. Substantial progress towards the development of a comprehensive mobile source inventory / impact model has been accomplished.